

*BERMUDALANA ARUBOIDES*, A NEW GENUS AND  
SPECIES OF TROGLOBITIC ISOPODA  
(CIROLANIDAE) FROM MARINE  
CAVES ON BERMUDA

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*Abstract.*—*Bermudalana aruboides*, a blind unpigmented cirolanid isopod representing a new genus, is described from inland marine caves on Bermuda. It is the first hypogean cirolanid known from Bermuda. The close resemblance between *Bermudalana* and *Arubolana*, known from brackish groundwater on Aruba, Netherlands Antilles, suggests that both were derived from a common marine ancestor.

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The inland marine caves of Bermuda contain a rich and diverse invertebrate fauna (Sket and Iliffe 1980). The extensive nature of the underwater portions of these limestone caves, some being more than 1.5 km in length (Iliffe 1980), and the presence of strong tidal currents passing through them have resulted in the establishment of a considerable range of biotopes. In coastal cave entrances and those cave passages with strong tidal currents, sponges, bryozoans, hydroids, and other encrusting organisms literally cover all rock surfaces. Deeper into the caves, where tidal currents become more diffuse, sponges and other associated fauna become far less numerous. In the deepest inland caves most remote from the sea, the walls are totally barren of encrusting organisms and only specially adapted troglobitic species are present. This zonation approximately corresponds to that recognized in terrestrial caves (Poulson and White 1969): a twilight zone near the entrance, a middle zone of complete darkness and variable temperature, and a zone of complete darkness and constant temperature in the deep interior. In marine caves as well as in terrestrial caves, the twilight (coastal entrance) zone has the largest and most diverse fauna; the middle zone has some species which may commute to the surface (bats and crickets in terrestrial caves; lobsters in marine caves). The deep interior cave, while being the most depauperate, possesses environmental and faunal aspects unique to caves.

The existence of marine troglobites is a relatively new discovery. As recently as 1965, Vandel stated that "animals (from marine caves) have not usually undergone noticeable modification" and thus "marine caves . . . have but a slight interest to the biospeleologist" (1965:8). In our faunal survey of Bermuda's marine caves, the following troglobitic species have so far been described: *Atlantasellus cavernicolus*, an isopod representing a new family (Sket 1979); *Somersiella sterri* and *Typhlatya iliffei*, two new species of caridean shrimp (Hart and Manning 1981); and *Mesonerilla prospersa*, a new archiannelid polychaete (Sterrer and Iliffe 1982). Additional new species described from Bermuda's caves which may or may not be troglobitic include *Miostephos leamingtonensis*, a new calanoid copepod (Yeatman 1980); and *Apseudes bermudeus*, a new hermaphroditic tanaidacean (Băcescu 1980). We here describe a new genus and species of troglobitic cirolanid isopod from deep interior marine caves on Bermuda.



Fig. 1. Church Cave, Bermuda, seen from entrance.

*Bermudalana*, new genus

*Diagnosis*.—Eyes absent. Without pigment except brown incisors of mandibles. Pleonites all free, all reaching lateral margin of pleon. Frontal lamina with keel. Clypeus produced ventrally into slender conical process. Peduncles of antenna 1 and 2 3- and 5-segmented; flagella with relatively few segments. Maxilla 2 reduced, palp and exopod lacking, endopod with only a few distal setae. Maxilliped with sparse setation, palp 4-segmented, endite with 1 retinaculum. Pereopods 1–3 prehensile; pereopods 4–7 slender, ambulatory. Pleopods 1–2 with undivided setose rami. Pleopods 3–5 with 2-segmented setose exopods and undivided endopods; endopods of pleopods 3–4 with a few apical setae, endopod of pleopod 5 without setae. Appendix masculina inserted subterminally. Penes well developed, narrowly cylindrical, separated at base.

*Type species*.—*Bermudalana aruboides*, new species.

*Etymology*.—From the locality, Bermuda, plus (*Ciro*)*lana*. Gender feminine.

*Bermudalana aruboides*, new species

Figs. 2–4

*Material*.—Bermuda: Church Cave (also known as Paynter's Vale Cave), Hamilton Parish, 11 July 1982, leg. T. M. Iliffe, 4 ♂ (3.9, 3.8, 3.6, 3.1 mm) and 2 ♀ (4.1, 3.3 mm) were collected from 7 to 10 m water depths with scuba using a suction bottle. Wonderland Cave (also known as Whitby Cave), Hamilton Parish, 19 May 1982, leg. T. M. Iliffe, 2 ♂ (3.7, 3.4 mm) and 3 ♀ (4.0, 4.0, ? mm) were collected from 10 to 15 m depths with scuba using a suction bottle. The 3.9 mm ♂ from Church Cave is the holotype (USNM 195020); the other specimens are

paratypes (Church Cave specimens USNM 195021, Wonderland Cave specimens USNM 195022).

*Distribution.*—Known only from the anchialine habitats of Church and Wonderland Caves, Bermuda.

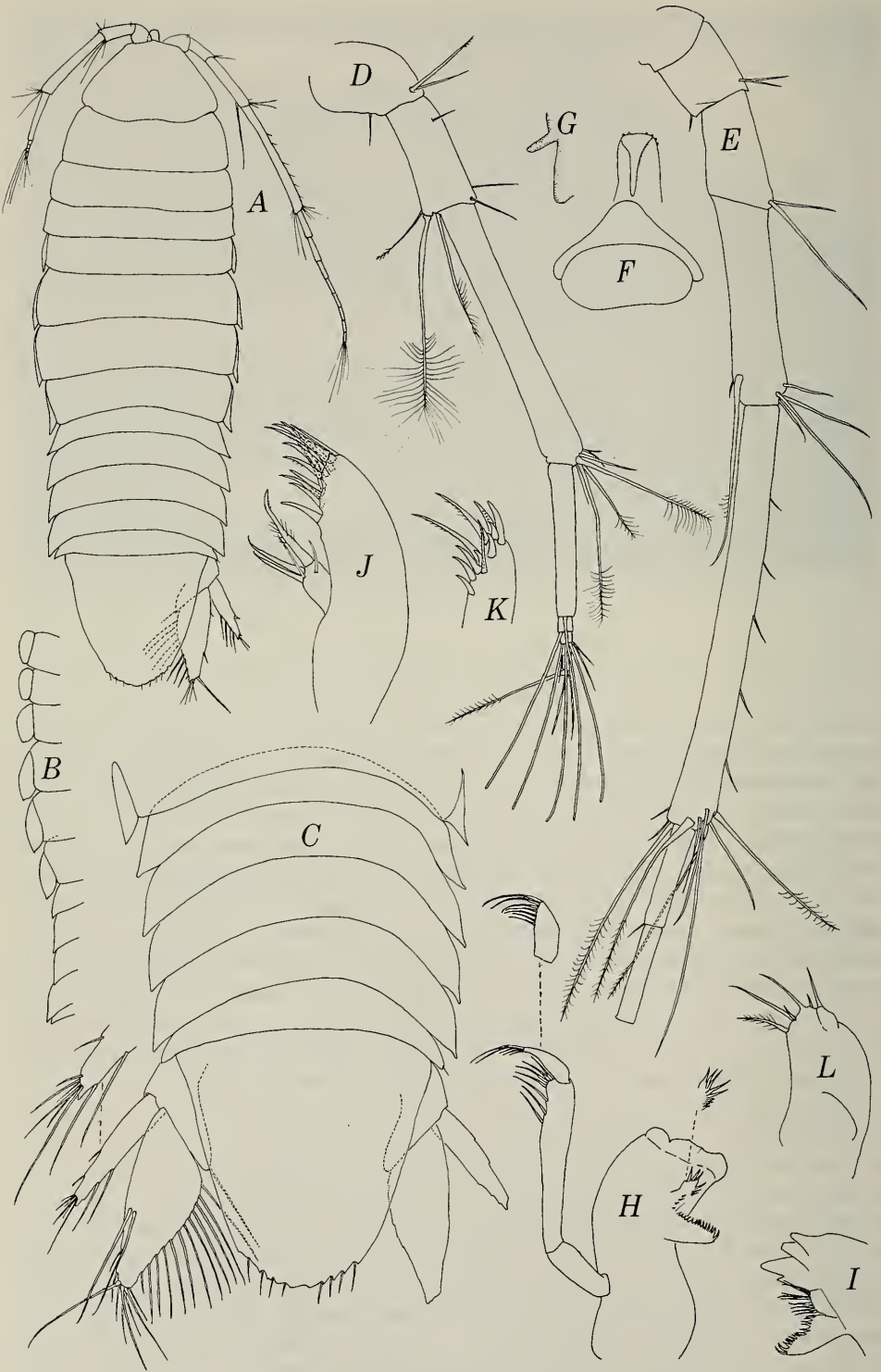
*Habitat.*—The Bermuda islands consist of a mid-ocean volcanic seamount capped with Pleistocene and Recent, marine and eolian limestones. Bermuda is one of the world's most geographically isolated islands, located 1000 km east of the North American continent in the section of the North Atlantic known as the Sargasso Sea. Bermuda has never been part of a continental land mass. The island's limestone caves were formed during low stands of sea level corresponding to periods of Pleistocene glaciation (Bretz 1960; Palmer *et al.* 1977; Iliffe 1981). As postglacial sea levels rose, much of the former extent of the caves was flooded by sea water. Approximately 200 inland caves are known from Bermuda, over half of which contain tidal, sea level pools.

Church Cave is located on the grounds of the Castle Harbour Hotel about 250 m linear distance from Castle Harbour, the nearest body of open salt water. The main entrance is about 26 m above sea level and consists of an opening 25 m wide by 15 m high in a collapse sink 25 m in diameter. Inside this entrance, a long steep breakdown slope descends to a sea level lake 35 m wide by 35 m across (Fig. 1). A small amount of sunlight from the entrance can reach one corner of the lake, but the rest remains in total darkness. The tides in this lake have an average range of 40% that of the open sea and have a lag time of about 107 minutes. Surface salinity is between 15.5 and 22.8‰, probably varying with rainfall, while at 1, 10, and 20 m depths, salinities are about 27, 34.5, and 35.3‰ respectively. Surface temperatures seasonally range from about 16 to 19°C, but temperatures in deeper waters (20.3°C at 20 m) remain nearly constant year round. The natural geothermal gradient has been proposed as a possible explanation for this anomalous temperature increase with depth (Iliffe *et al.* 1983). The sides of the lake are undercut, with the bottom being 20 m at the deepest point and floored with breakdown blocks of considerable size, but little fine sediments. The underwater parts of the cave are abundantly decorated with delicate speleothems, including "soda straws" and helectites, all perfectly preserved despite their long submersion. The presence of such speleothems, which only form in air, in all explored parts of the underwater caves indicates that the caves were dry during the prolonged periods of Pleistocene glaciation when sea levels were 80 to 100 m lower than today. Only one underwater cave passage has been found extending away from the lake and this ends after 45 m in a flowstone plug.

Wonderland Cave is located 2 km northwest of Church Cave and is 420 m from Castle Harbour. It was once operated as a commercial cave, but has not been used for such purposes since the 1940s. A steep set of 89 steps descends from the small entrance building located at an elevation of 24 m to a large room developed along a linear inclined fissure. The room contains a sea level lake 60 m long by as much as 12 m wide. This lake is 18 m at the deepest point and floored by large slabs of breakdown. A 50 m long underwater passage extends from the far side of the lake to re-emerge in an air-filled breakdown room. No other underwater passages have been found. As in Church Cave, many large stalactites and stalagmites are present even in the deepest parts of the lake.

All specimens of *Bermudalana* were taken from open waters of the lakes by





cave divers as the animals were observed swimming several meters above the bottom. Divers used a bright underwater light to scan the very clear cave waters. Any animals or particles in the water would flash as the light beam passed across them, effectively locating them. The swimming behavior of *Bermudalana* is most likely a result of the animal's food locating actions and not an escape reaction. No specimens were ever observed crawling over the substrate. The lack of any encrusting organisms with only planktonic or nektonic species being observed also supports the idea that *Bermudalana* is a predator, capturing its food from open waters. Other animals collected or observed from Church and Wonderland Caves include a halocyprid ostracod now under study, a peracarid representing a new order (Bowman and Iliffe, in preparation), and a caridean shrimp, probably *Typhlatya iliffei*. Copepods are probably also present as they have been found in nearly every marine cave studied in Bermuda. It is likely that *Bermudalana* will also be found in other far inland caves of Bermuda as they are investigated.

*Description.*—Body moderately slender, slightly more than  $3\times$  as long as wide, length about 4 mm. Anterior margin of head slightly concave on either side of minute rostrum, about  $1.7\times$  as wide as long. Frontal lamina visible in dorsal view, about a third longer than wide, ventral surface produced into carina. Clypeus in lateral view produced into rather slender cylindrical process.

Pereonites 1 and 5–7 subequal in length, distinctly longer than the subequal pereonites 2–4; all pereonites with rounded posteroventral corners. Posteroventral corners of coxae 2–4 rounded, of 5–7 with small points. Pleon (excluding telson) about half length of pereon; pleonites 1–4 subequal in length, pleonite 5 shorter and slightly narrower, epimera all ending in small points. Telson linguiform, slightly shorter than width at base, posterior sixth with 4 setae on each side set in marginal notches; marginal spines absent.

Antenna 1 reaching slightly beyond posterior margin of pereonite 1; peduncle segment 3 very long, peduncle segments 2–3 with long plumose distal setae; flagellum 5-segmented, 1st segment nearly  $3\times$  as long as remaining segments combined, all segments with long esthetes. Antenna 2 reaching posterior margin of pereonite 6; segments of peduncle successively longer; flagellum 8-segmented.

Incisors of mandibles with 3 cusps, cusps more deeply separated in right mandible; left lacinia with 10 spines, right lacinia with 9 spines; molar with 14 spines; segment 2 of palp about  $2.5\times$  as long as segment 1, with about 7 marginal setae on distal fifth; segment 3 slightly shorter than segment 1, with about 7 setae.

Maxilla 1 exopod apex with 10 spines, 2 much longer than others, and a central seta; endopod with 3 apical spines and 2 subterminal setae. Maxilla 2 reduced to single ramus armed apically with 4 long and 2 short setae. Maxilliped endite with 2 apical plumose setae.

Pereopods 1–3 subchelate, dactyl closing against palm of expanded propus; palm bearing distally a spine with posterior setule, 3–5 thickset spines, and 8–15

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Fig. 2. *Bermudalana aruboides*: A, Habitus, dorsal; B, Coxae and epimera, lateral; C, Pleon and telson, dorsal; D, Antenna 1; E, Antenna 2 peduncle; F, Frontal process, clypeus, and labrum; G, Clypeus, lateral; H, Left mandible; I, Incisor, lacinia, and molar of right mandible; J, Maxilla 1; K, Maxilla 1 exopod, apex; L, Maxilla 2.

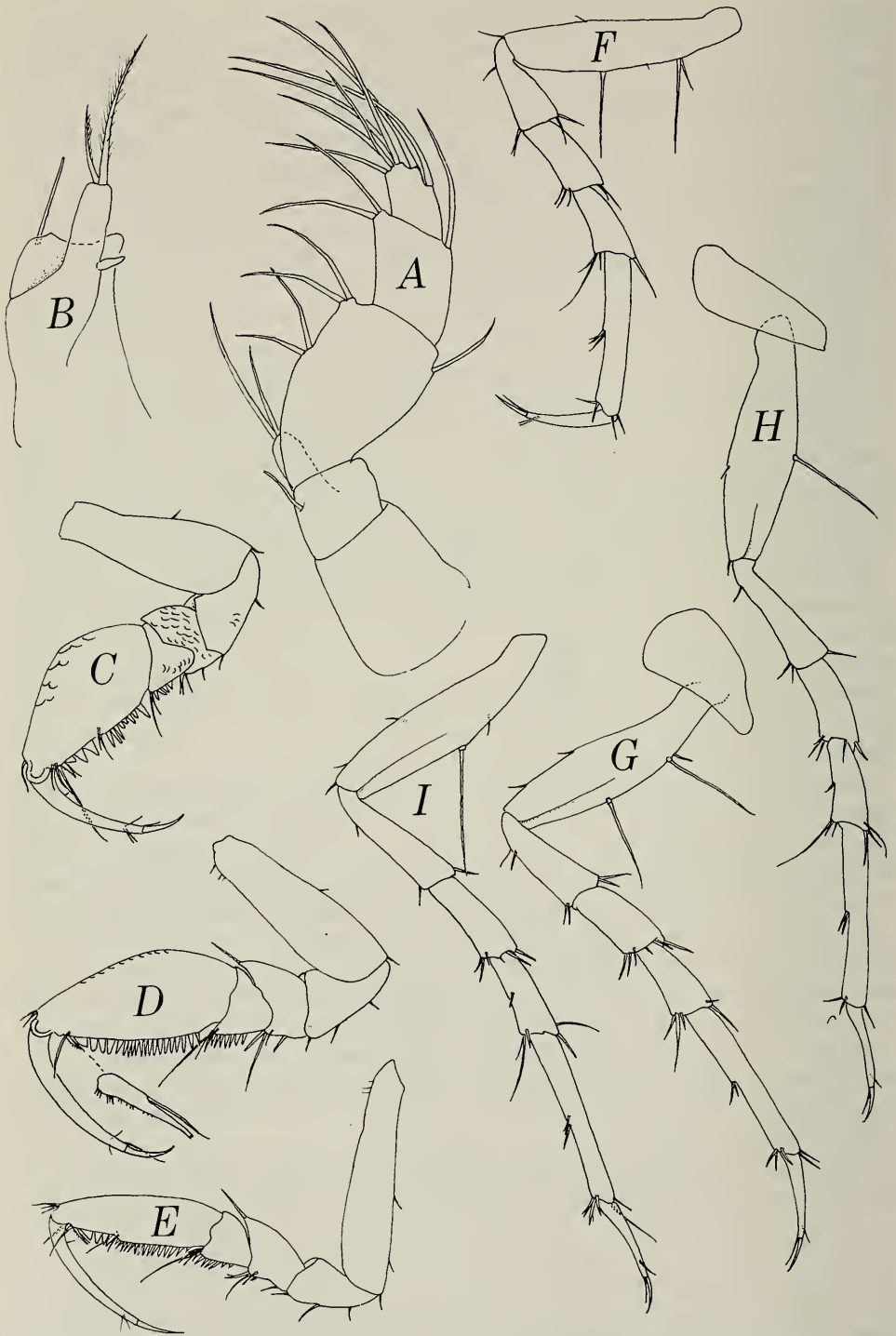


Fig. 3. *Bermudalana aruboides*: A, Maxilliped; B, Maxilliped endite; C-I, Pereopods 1-7.

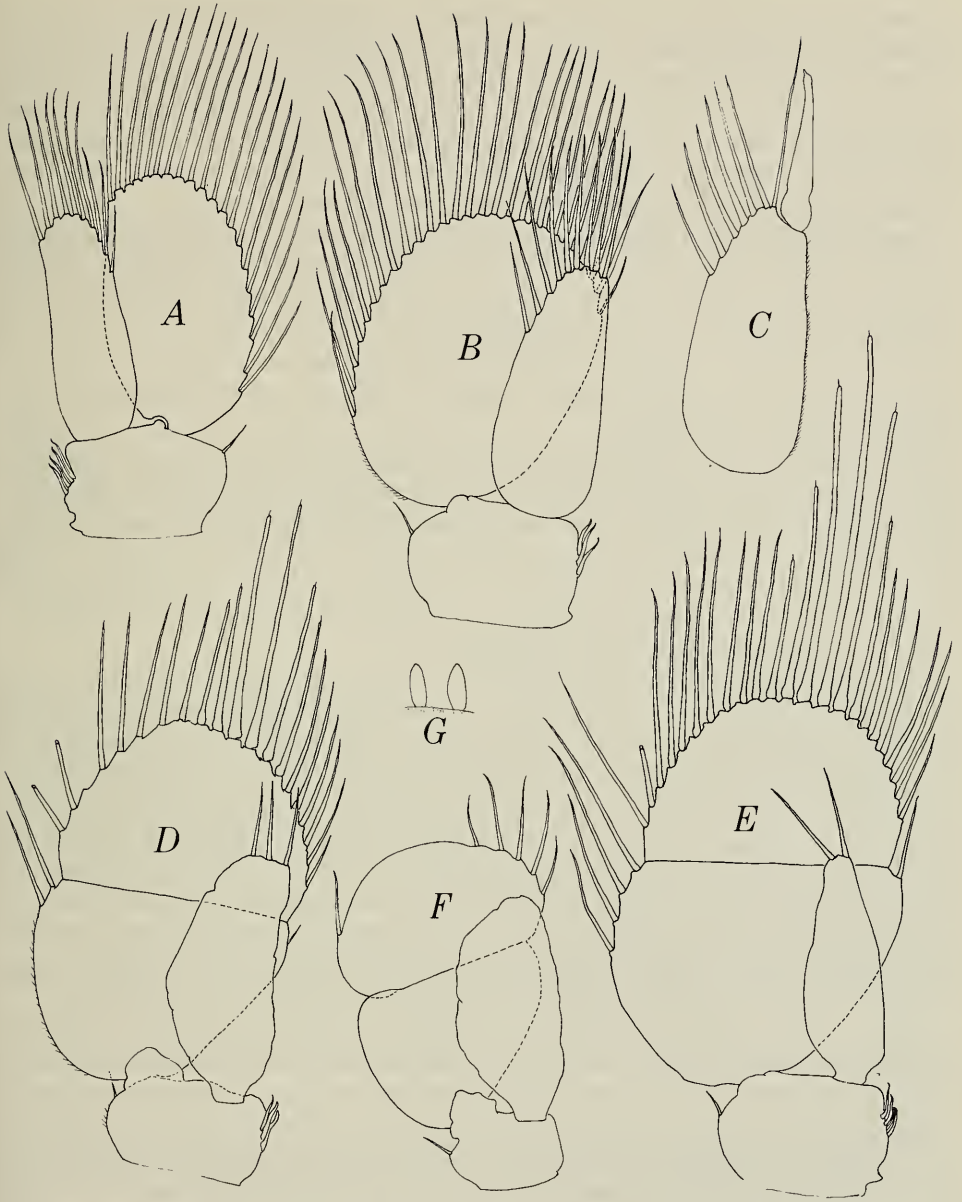


Fig. 4. *Bermudalana aruboides*: A-B, Pleopods 1-2, ♀; C, Pleopod 2 endopod, ♂; D-F, Pleopods 3-5, ♀; G, Penes, ♂.

more slender spines; posterior margin of carpus with 4-7 slender spines. Propus of pereopod 2 slightly less expanded but longer than that of pereopod 1; propus of pereopod 3 slender. Pereopods 4-7 slender, sparsely armed with spines, mostly at distal ends of segments; basipods with long setae on posterior margins, 2 on pereopods 4-5, 1 on pereopods 6-7.



Exopods of pleopods 1–4 with long marginal setae, some of those on apex of pleopods 3–4 longer, thicker, and ending in terminal setule. Exopod of pleopod 5 with 4 medial and 1 lateral setae on distal segment; apex without setae. Endopods of pleopods 3–4 much narrower than very broad exopods, armed with 2 apical setae in pleopod 3, 3 in pleopod 4; endopod of pleopod 5 without setae. Appendix masculina of ♂ pleopod 2 about  $0.6\times$  as long as endopod, with constriction near base, curving slightly laterally and ending acutely.

Uropod endopod pyriform, about a third longer and  $3\times$  as wide as sublinear exopod; medial margin and apex armed with long setae, lateral margin with 2 short setae in distal part and 2 long setae set in from margin slightly distal to midlength. Exopod with 2 long medial setae, 2 short lateral setae, and cluster of setae lateral to apex, medial part of which is produced into narrow process.

*Etymology.*—The specific name refers to the important similarities between *Bermudalana* and *Arubolana*.

*Relationships.*—The combination of five pleonites reaching the lateral margin of the pleon and pereopods 1–3 prehensile is found in two genera of Cirolanidae, *Bahalana* Carpenter, 1981, with one species from Lighthouse Cave, San Salvatore Island, Bahamas, and *Sphaeromides* Dollfus, 1897, with three species from caves adjacent to the Mediterranean. These genera differ from *Bermudalana* in having a normally developed maxilla 2, a 5-segmented palp on the maxilliped, and a basally inserted appendix masculina.

The closest relative of *Bermudalana* is *Arubolana* Botosaneanu and Stock, 1979, represented by a single species, *A. inula* Botosaneanu and Stock, from brackish groundwater in Aruba, Netherlands Antilles. The two genera have in common reduced segmentation of antennae 1 and 2, a greatly reduced maxilla 2, a maxilliped with a 4-segmented palp, an appendix masculina inserted subterminally, and interrupted marginal setae on the exopod of pleopod 5. *Arubolana* differs in having pleonite 5 overlapped laterally by pleonite 4 and only pereopods 1–2 prehensile. These differences are usually believed to be of generic value in the Cirolanidae, hence we have proposed a new genus for the Bermuda cirolanid. We realize, however, that a plausible case could be made for assigning the latter to *Arubolana* or for recognizing *Bermudalana* as a subgenus of *Arubolana*.

*Origin.*—The common possession by *Arubolana* and *Bermudalana* of several specialized character-states not found elsewhere in the Cirolanidae can be explained best by their evolution from a common ancestor. Convergent evolution could be evoked for a single character-state but is highly unlikely for such a combination of several character-states. Aruba and Bermuda are separated by about 1400 miles (2250 km) and water of abyssal depths; dispersal from one of these islands to the other by a small troglobitic isopod would seem to be a remote possibility. Rafting on floating objects carried from Aruba to Bermuda via the Gulf Stream cannot be disproven, but we do not consider it a serious possibility. The origin of the two species from a common marine ancestral species is a more believable alternative, but two difficulties must be faced. 1. Cirolanids are rarely found at the abyssal depths ( $>2000$  m) of most of the Atlantic between Aruba and Bermuda. Depths recorded for three blind deep-sea species of *Cirolana* are *C. caeca* Dollfus, 1903, 1200–2500 m; *C. anocula* Kensley, in press, 750 m; *C. californiensis* Schultz, 1966, 700–2000 m (Brusca and Ninos 1978). 2. Prehensile pereopods in the Cirolanidae are known only in hypogean species. The reason



for this is not known, but might be related to a shift in feeding from scavenging to predation in cave cirrolanids. Carpenter (1981) reports that *Bahalana geracei* holds its prey firmly with prehensile pereopods 1–3 and bites off small pieces with its mandibles.

Nevertheless, Aruba and Bermuda have never been connected by land and if *Arubolana* and *Bermudalana* had a common ancestor, as we firmly believe, it must have been a marine cirrolanid. It is possible that the ancestral cirrolanid lacked prehensile pereopods and that the latter evolved independently in the two genera after reaching their present localities.

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